According to diatom data [Tolstobrova et. al., 2016], the biological efficiency of the basin significantly increased during isolation time. The number of *Pinus* pollen increased and single grains of *Picea* emerged, while *Betula nana* totally disappeared.

At the latest stage of isolation and during post-isolation time, the diatoms continued to change towards the increase of indifferents and halophobs. After isolation, Osinovoe Lake became a relatively deep oligotrophic reservoir. *Betula* and *Pinus* dominate in the pollen spectra and proportion of *Picea* increases. Up to sediment succession, *Betula nana* disappears and Poaceae and spores (mostly Polypodiaceae and Lycopodiaceae) decrease. Diatoms and the spore-pollen record suggest an environmental warming, which took place during that time.

At the early stage of autonomous Osinovoe Lake development, *Betula* pollen dominated the pollen spectra, proportion of Pinus pollen increased and *Betula* pollen gradually declined. Single Picea pollen grains appeared in the samples correlated to the middle stage of isolation; its proportion rose during the lake development.

Obtained results are in good correlation with those earlier published by Elina with coauthors [Elina et al., 2010] and Solovieva &Jones [Solovieva &Jones, 2002]. This fact confirms a suggestion that pine-birch forest with dominated *Betula* and *Pinus* additive, similar to contemporary Boreal forests (northern taiga), grew in the central Kola Peninsula in the early Holocene. We obtained preliminary data and recognized paleoenvironment affected by the climate change in the paleo-Lake Imandra catchment area.

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REFERENCES

1. Atlas Murmanskoi oblasti // Moskva: Glavnoye upravleniye geodezii i kartorgafii pri sovete ministrov SSSR. – 1971.

2. Elina G.A. Late Glacial and Holocene paleovegetation and paleogeography of Eastern Fennoscandia. – 2010. – P. 304.

3. Nikolaeva S.B. Rekonstrukciya paleogeograficheskih obstanovok golocena v raione ozera Imandra (Kol'skii region): rezul'taty paleolimnologicheskih issledovanii // Trudy Kol'skogo nauchnogo tsentra RAN. – 2015. – Vol. 5. – P. 34–47.

4. Solovieva N. A multiproxy record of Holocene environmental changes in the central Kola Peninsula, northwest Russia // J. Quaternary. – 2002. – Vol. 17. – P. 303–318.

5. Tolstobrova A.N. Late glacial and postglacial history of Lake Osinovoye (Kola Region) inferred from sedimentary diatom assemblages // Transactions of the Karelian Research Centre of the Russian Academy of Sciences. – 2016. – № 5. – P. 106–116.

LONG-TERM TRANSFORMATIONS ASSESSMENT FOR THE LAKE ECOSYSTEMS OF THE NORTHERN EUROPE AND WESTERN SIBERIA BY THE METHOD OF DIATOM COMPLEXES TAXONOMIC PROPORTIONS GRAPHIC ANALYSIS

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Initially, the method of graphical analysis (MGA) was developed in the spatial studies of diatom data complexes from modern lake sediments of the Kola Peninsula. Later lakes from different regions of European Russia were studied (Razumovsky, Moiseenko, 2009; Razumovsky, 2012). More than 150 lakes were explored in total. The diatomic complexes structural transformations in time was studied by bottom sediment columns from 21 lakes, which are located in different landscape and climatic regions of the European Russia from the Kola Peninsula to Caucasus (Razumovsky, 2012; Razumovsky, 2014).

MGA core is the following: we putting on the X-axis is the number of identified species taxa of and lower ranks (hereinafter referred to as taxa), and Y-axis is their relative abundance. The taxa are ranked by relative abundance in the direction of its decline. According to the relative numbers the taxons divided into a groups: dominant (usually at least 8-10%), related (more than 1-2%) and rare (usually less than 1%). As a result, the initial graph or histogram is built in the linear coordinate system. Using the developed method of analysis, the lakes were divided into two spatial categories: with a water surface area of less than 1 km^2 (small) and with a water surface area of 1 to 4 km^2 (medium).

The analysis of the obtained data is carried out in a linear and logarithmic coordinate system.

In the linear coordinate system, two types of natural undisturbed taxonomic proportions graphs of diatom complexes were distinguished.

One of them is close to the exponential dependence and is typical for small lakes (the "simple" systems). For the medium-sized lakes (the "complex" systems) form of the obtained graphs has a certain similarity with logistic dependence (Shitikov et al., 2005).

In the logarithmic coordinate system, not the graphs themselves, but their trends represented by the resulting straight lines are analyzed. These lines forms the generation of certain outlines.

In the logarithmic coordinate system analysis, three main scenarios of spatial-temporal transformation of taxonomic proportions were identified.

The most pronounced (indicative) differentiation by dimension categories is typical for tundra and forest-tundra zones of the European part of Russia. This is due to the landscape and climatic features of the Kola Peninsula. The differentiation in the size of lakes is expressed in different types of taxonomic proportions distribution and in different types of spatial-temporal transformation.

From 2001 to 2010, MGA was used in the study of lakes (mostly small) in other areas of the European part of Russia. 53 lakes was studied in total, 15 of which are located in zones of tundra and forest-tundra, 11 from the zone of Northern taiga, 11 from the zone of middle taiga, 13 from the zone of southern taiga and pottage and 3 of the steppe zone.

In addition, 26 small lakes in the highlands (Caucasus) were studied. The following patterns are observed in the direction from North to South:

1. Weakening, "erosion" of identification features by categories of dimension between small and medium lakes in the plains.

2. Differentiation in the category of small lakes in two spatial transformation scenarios. This differentiation is particularly pronounced in the high mountains (Caucasus).

On the territory of Western Siberia, the pronounced differentiation of taxonomic proportions in the linear coordinate system (between small and medium lakes) extends to the South, up to the Northern taiga zone inclusive. Accordingly, the weakening of this differentiation is confined to the middle taiga and sub-taiga zone. The secondary differentiation within the lakes of small dimension by two types of spatial transformation is confined to the sub-taiga and forest-steppe zones.

The analysis of the lakes of Western Siberia by the bottom sediment columns revealed the previously unrecognized type of transformation: with the change of climatic conditions towards warming, transformations in the lakes of small dimension are observed in a more complex scenario typical for the lakes of medium dimension. However, due to shallow depth of the lakes, the reverse transformation happens and the lakes returns to the script, typical for the lake ecosystem of small size.

We think this is due to the objective impossibility of self-organization of the ecosystem at a higher level because of the insufficient amount of ecological space (depth), which hinders further potential development at a higher level. Such a scenario of transformation in the European part of Russia was not observed yet.

REFERENCES

1. Razumovsky V.L. Assessment of the ecological state of the high-mountain lakes of the Elbrus region on the results of diatoms analysis / V.L. Razumovsky // Water resources. – 2014. – Vol. 41, № 2. – P. 200–205.

2. Razumovsky L.V. Assessment of transformation of lake ecosystems by diatom analysis / L.V. Razumovsky // M.: GEOS. – 2012. – P. 199.

3. Razumovsky L. V. Evaluation of spatial-temporal transformation of lake ecosystems by the method of diatom analysis / L.V. Razumovsky, T.I. Moiseenko // Doklady RAS. – 2009. – Vol. 429, № 2. – P. 274–277.

4. Shitikov V.K. Quantitative Hydroecology: methods, criteria, solutions / V.K. Shitikov, G.S. Rozenberg, T.D. Zinchenko // Science. – № 1. – 2005. – P. 281.

CIRCULATION REGIME AND REDOX-CONDITIONS IN SALINE LAKE SHIRA (KHAKASIA, SIBERIA): FROM MODERN OBSERVATIONS TO PALEO-RECONSTRUCTION

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Meromictic lakes are lakes in which the deep recirculation does not include the entire water body. In meromictic state the nutrients accumulated in the monimolimnion with the sedimentation flow of organics are not available for the primary producers. Thus, in case of meromixis destruction, nutrients are released from the monimolimnion, resulting in outbreaks of phytoplankton bloom, i.e. in deterioration of water quality and changes in the species composition of plankton organisms. The weather conditions are among the main reasons for destruction of meromixis. Another reason for destruction of meromixis is change in water level. Since the change in mixing regime gives rise to changes in the composition of the sediments, the alterations between mixing regimes can be reconstructed for the long period of a lake history (Schmidt et al., 2002). In particular, hydraulically closed water bodies located in arid climates sensitively react by changes in water level to the changes in the balance of precipitation and evaporation in the area. In turn, the change in water level may result in change in mixing regime. Therefore reconstruction of mixing regimes of closed lakes provides valuable information on their level dynamics, consequently – about effective moisture of local climate.

Lake Shira (N 54.30, E 90.11) is located in Southern Siberia, in the steppe zone of the northern part of the Minusinsk valley (Republic of Khakassia, Russia). The average salinity in the mixolimnion during the summer stratification is about 15 g l^{-1}, and in the monimolimnion — about 19 g l^{-1} We analyzed the long-term field data on the vertical structure of Lake Shira and demonstrated for the first time the documented change in the lake stratification regime from meromictic to holomictic (Rogozin et al., 2017). The disappearance of purple sulfur bacteria from monimolimnion was a consequence of meromixis breakdown.

It was shown that in the period from 2002 to 2007 an increased inflow of fresh water caused the lake level rise, increasing the stability of the water column and consequently decreasing the depth of the autumn mixing. In the period from 2007 to 2015 the water level did not increase, reducing the stability of the water column and making the lake mixolimnion more sensitive to the wind stress. We assume that the most influential factor contributing to the winter mixing in 2015 was strong wind action due to early ice melt in the spring of 2014. The established causal relationship between meromixis stability and the level increase can be used for the reconstruction of paleo-climate humidity based on the indicators of anoxia in bottom sediments.

From bottom sediments of saline closed Lake Shira we estimated the switches between meromictic and holomictic conditions caused by climate-induced fluctuations of water level. The fossil carotenoid of phototrophic sulfur bacteria (okenone) was considered as a proxy of anoxia in water column (Zykov et al., 2012). Our latest observations on purple sulfur bacteria in Lake Shira confirmed that their biomass tends to increase in years of 2002-2007 when stable meromixis took place in the lake due to level increase. And vice versa: in the years of 2008-2016 the decrease in purple sulfur bacteria was correlated with constant level and weak meromixis (Rogozin et al., 2017). So we presume that